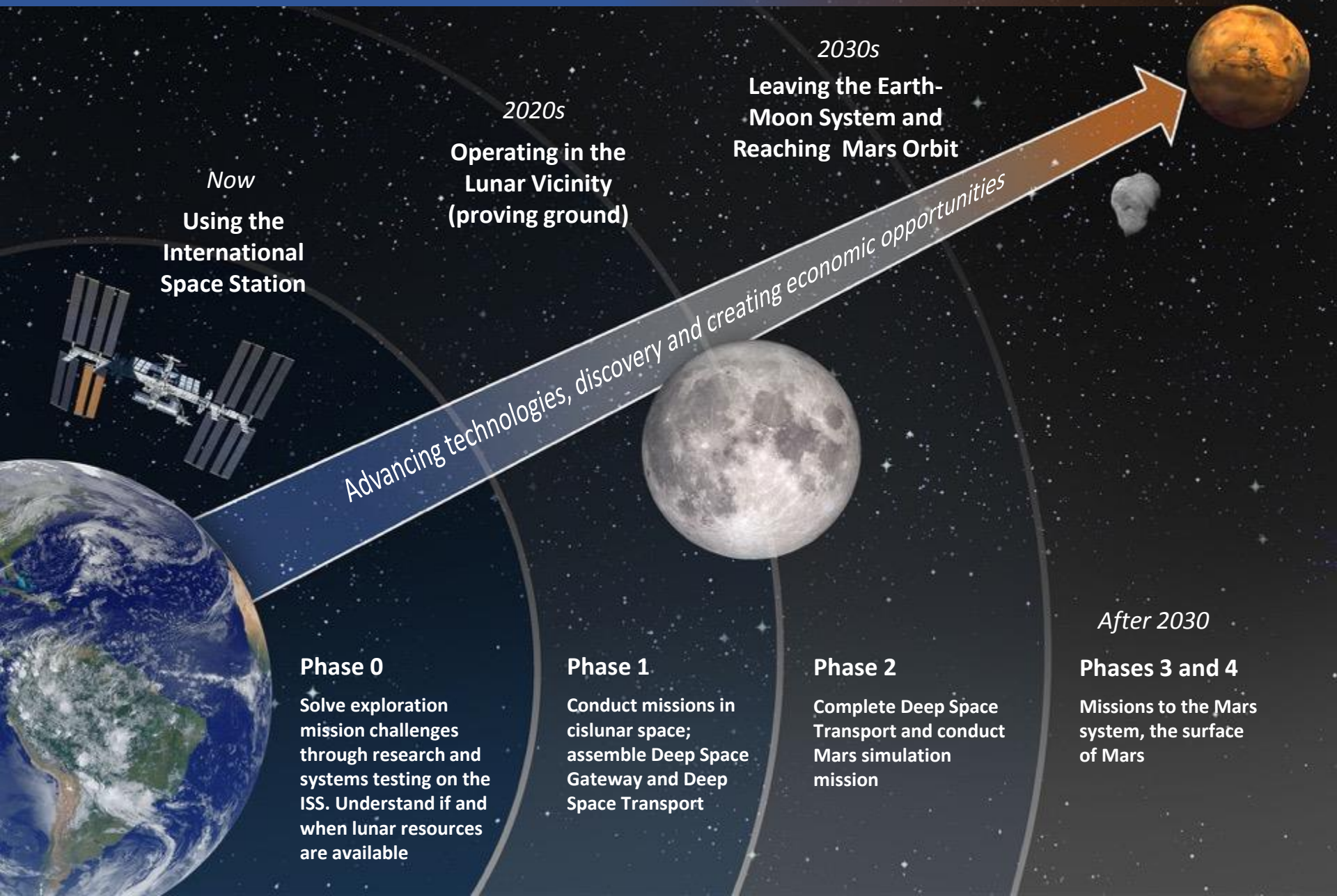
# Challenges of Human Exploration of Mars

Jose Núñez, PhD, PE
NASA Kennedy Space Center

# Outline

- Vision
  - Achieving Earth Independence
- International Space Exploration Coordination Group
- Capabilities and Enablers
  - Spaceport Evolution
  - Legal Framework
  - Commercial Partnerships
- Challenges to getting to the Vision
- Video

# Vision - Exploring Space In Partnership




NASA'S JOURNEY TO
MARS
SPACE PIONEERING:
Achieving
Earth Independence

# Challenges of "Living on Mars"

- Transportation (to/from the surface)
- Radiation Protection
- Food
- Water
- Shelter
- Energy Production
- Oxygen Production
- Improved Communications

# What does your Vision of "Living on Mars" look like?

Purpose

- Commercial
- Government
- Vacation
- Industry
- Species Survival
- Other?

Scale

- Outpost
- Community
- City
- Nation(s)

# Learning Outcomes

## Technical

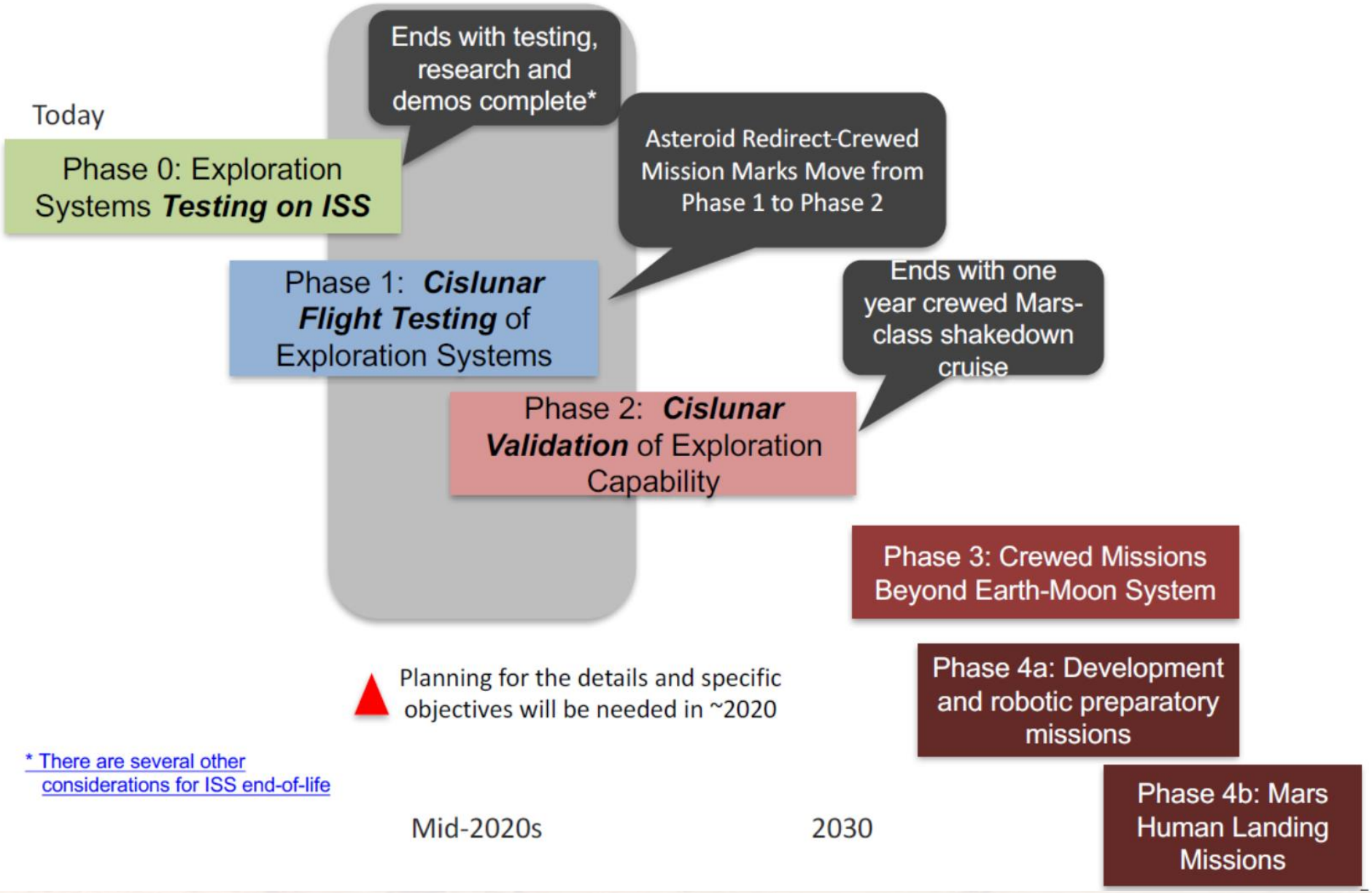
- Challenge and risk analysis related to operations on Mars
- Government Deep space architecture elements
- Technical challenges and risks for 'Living on Mars'
- NASA operational plans to support Mars Missions
- Technical aspects of in-situ resource utilization related to operations on Mars

## Gap Analysis

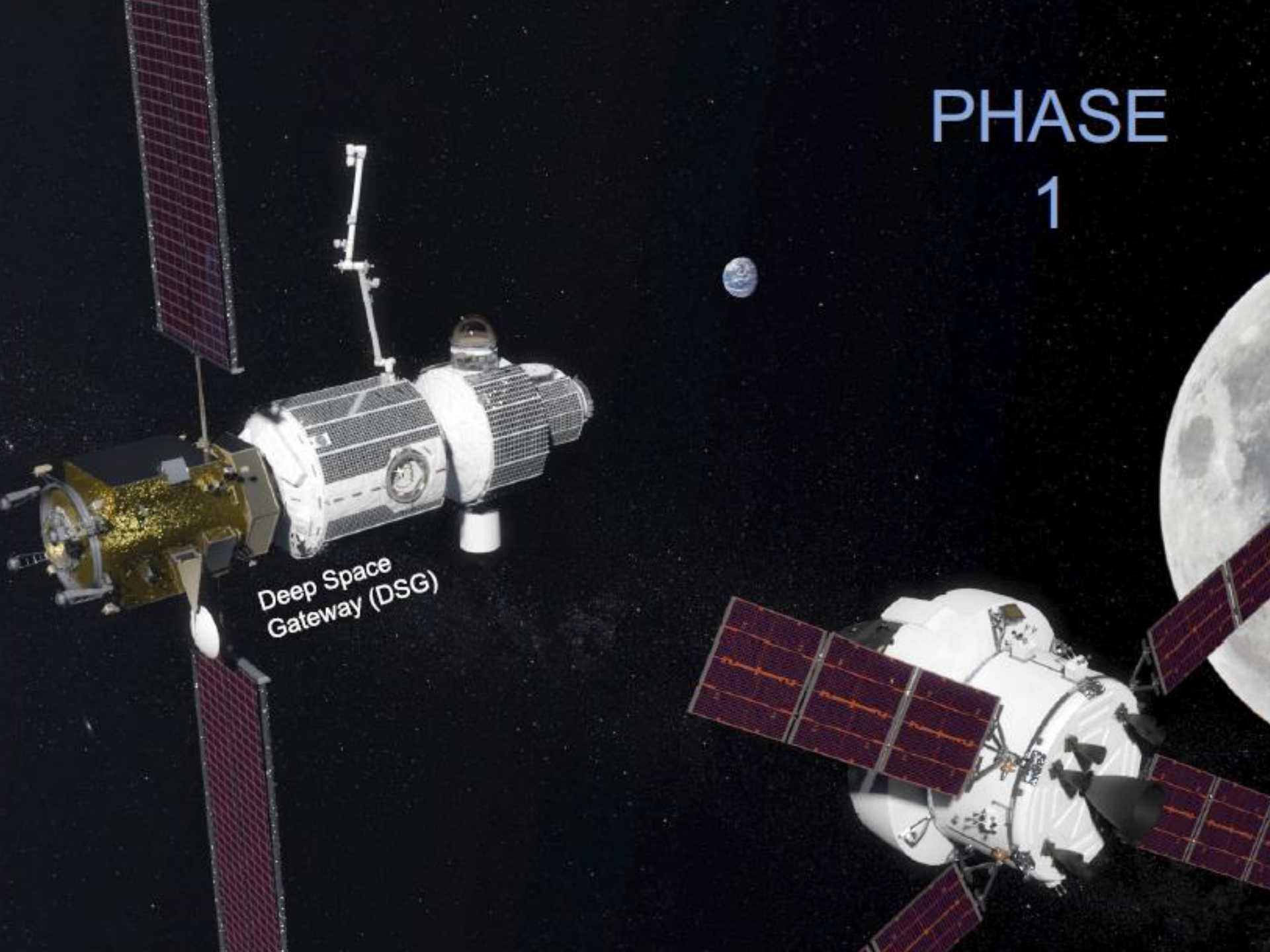
- Interdisciplinary team skills to quickly define a vision
- Identify gap between vision and  current Technology Readiness Level (TRL)
- Identify One Key Development as critical to enabling vision

# NASA plans

# Human Space Exploration Phases From ISS to the Surface of Mars
**as of November 2016**



# International Space Station

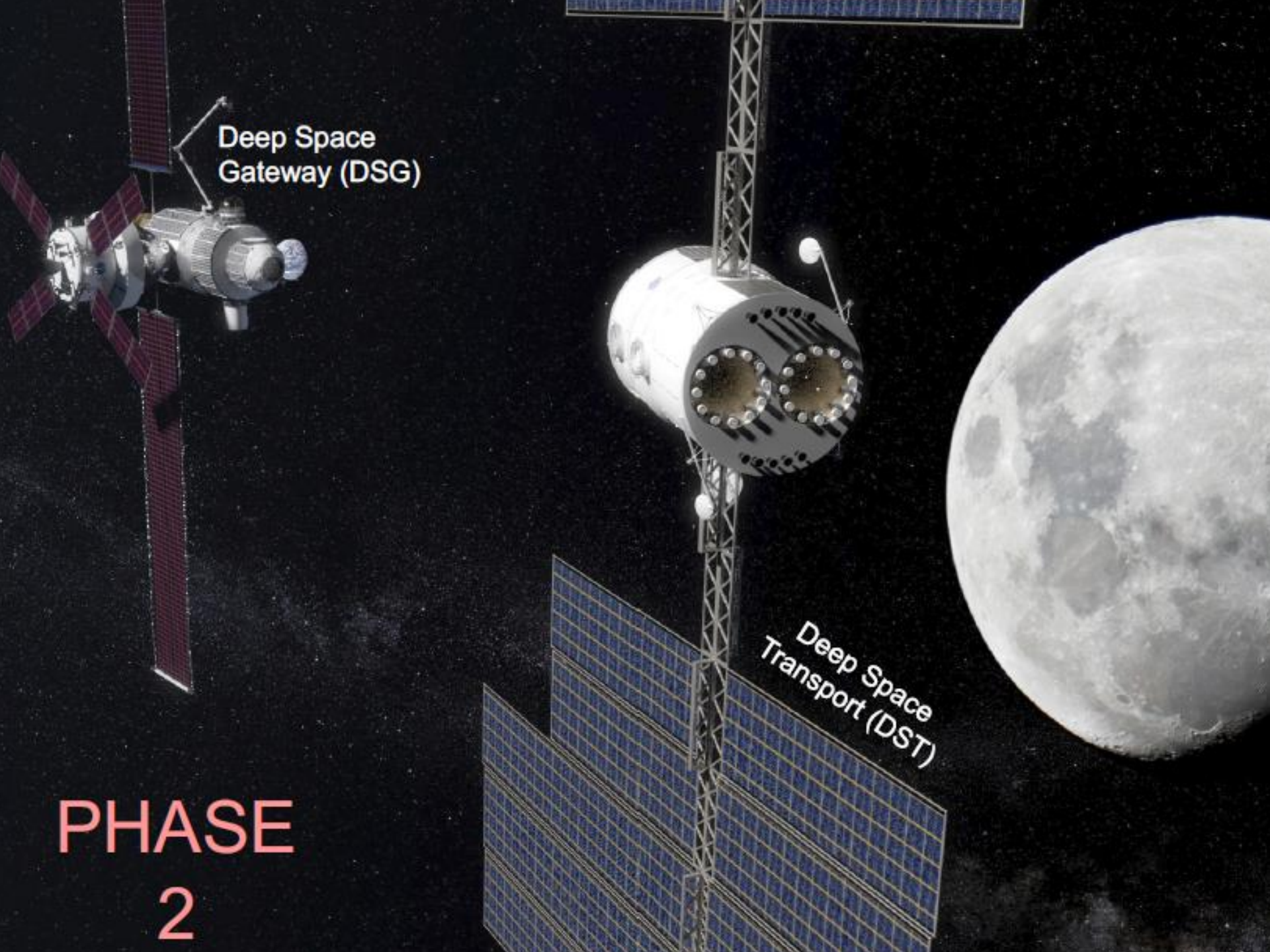

PHASE
1
Deep Space
Gateway (DSG)

# Deep Space Gateway Functionality

- **Assumptions**
  - Deep Space Gateway provides ability to support multiple NASA, U.S. commercial, and international partner objectives in Phase 1 and beyond
  - The Gateway is designed for deep space environments
    - Supports (with Orion docked) crew of 4 for total mission up to 42 days
    - Supports buildup of the Deep Space Transport
    - Open trade for compatibility for operations in Low Lunar Orbit

- **Emphasis on defining early Phase 1 elements**
  - Gateway Power Propulsion Bus
  - Gateway Habitat
  - Logistics Strategy

- **Future work to refine later elements; early feasibility trades complete**
  - Airlock
  - Deep Space Transport


Deep Space
Gateway (DSG)
Deep Space
Transport (DST)
PHASE
2

# Deep Space Transport Functionality

- **Assumptions**
  - Deep Space Transport provides habitation and transportation needs for transporting crew into deep space including supporting human Mars-class missions
  - The Transport system life will be designed for:
    - Reused for 3 Mars-class missions with resupply and minimal maintenance
    - Crew of 4 for 1,000 day-class missions in deep space
    - Launched on one SLS 1B cargo vehicle - resupply and minimal outfitting to be performed in cislunar space

- **Emphasis on supporting shakedown cruise by 2029**
  - Shakedown cruise to be performed in lunar vicinity
  - Utilizes deep space interfaces and common design standards

- **Future work trades**
  - Shakedown cruise objectives
  - Mars reference mission functional requirements

# How are we leading future human exploration?

- Maximizing utilization of the International Space Station
- Actively promoting LEO commercialization
- Resolving the human health and performance challenges
- Expanding partnerships with commercial industry
- Growing international partnerships
- Building the critical *Deep Space Infrastructure*
- Enabling the capabilities to explore multiple destinations

# International Space Exploration Coordination Group

# International Space Exploration Coordination Group (ISECG)















# International Space Exploration Coordination Group

**Need:** Coordinate multiple Space Agencies to achieve a shared vision of coordinated human and robotic space exploration focused on Solar System destinations where humans may one day live and work.

**Benefits:**

- Scientific Knowledge
- Sustained Human Presence
- Expand Economic Influence
- Global Partnership
- Inspiration & Education

**Goals:**

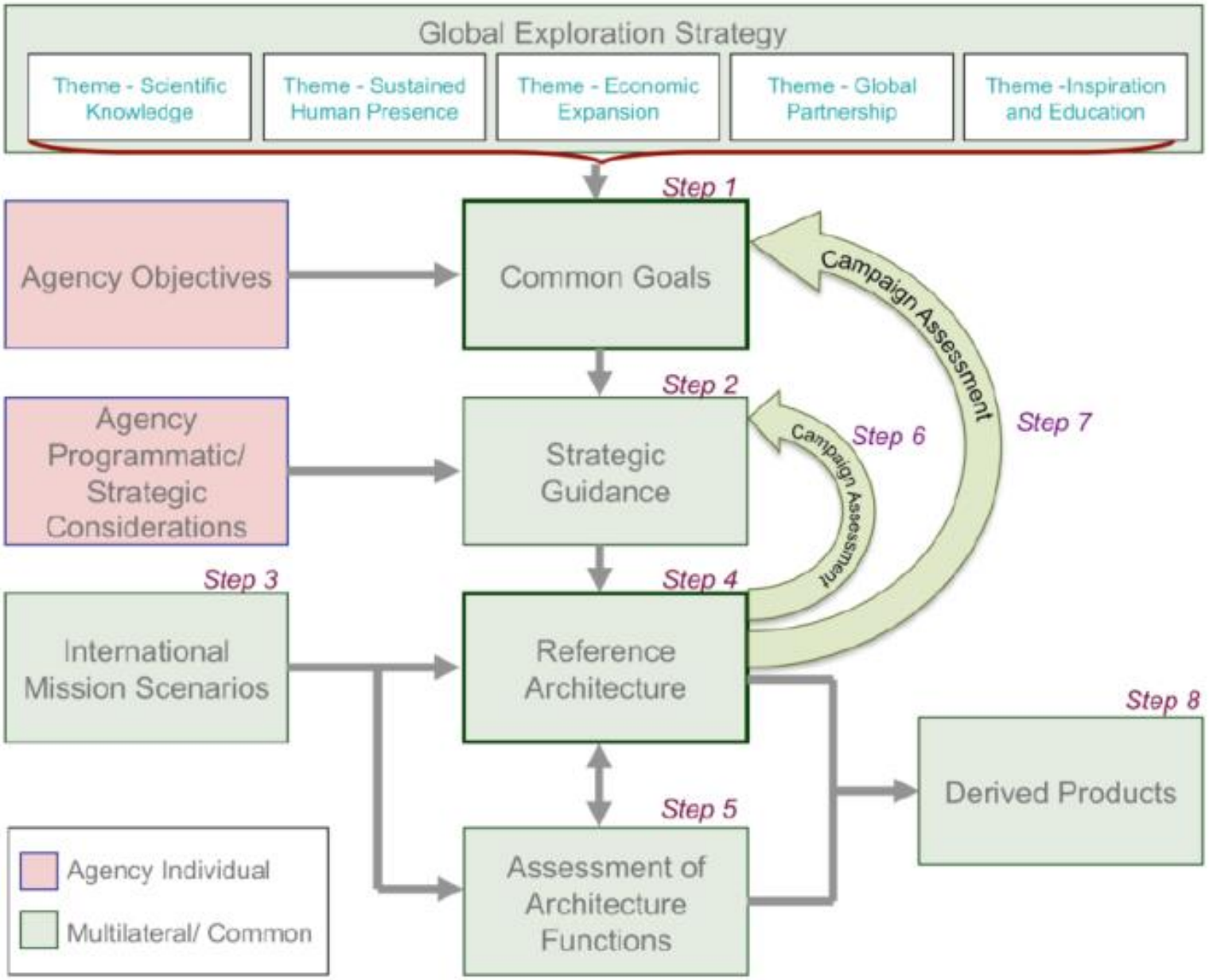
- Search for Life
- Extend Human Presence
- Develop Exploration Technologies and Capabilities
- Perform Science to Support Human Exploration
- Stimulate Economic Expansion
- Perform Space, Earth, and Applied Science
- Engage the Public in Exploration
- Enhance Earth Safety

# International Space Exploration Coordination Group

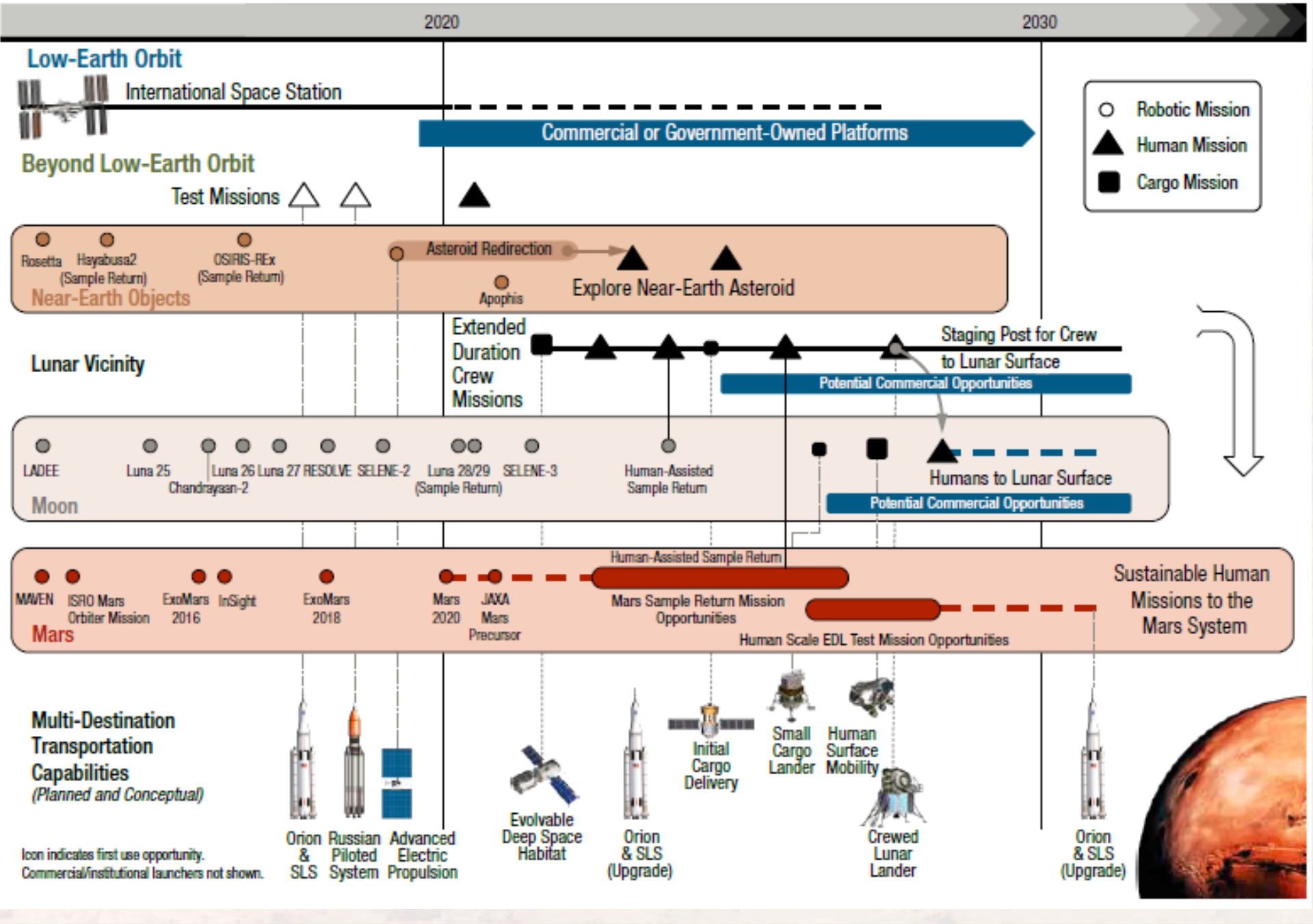
**Objective:** Destination specific Objectives were developed by ISECG, reference ISECG website

**Mission**: Develop Global Exploration Roadmap (GER) as a Reference Architecture

- GER 1.0 released Sept 2011
- GER 2.0 released August 2013
- GER 3.0 under development
- https://www.globalspaceexploration.org/


Global Exploration Strategy
Theme - Scientific Knowledge
Theme - Sustained Human Presence
Theme - Economic Expansion
Theme - Global Partnership
Theme -Inspiration and Education
Step 1
Agency Objectives
Common Goals
Campaign Assessment
Step 7
Step 2
Agency Programmatic/ Strategic Considerations
Strategic Guidance
Step 6
Campaign Assessment
Step 3
Step 4
International Mission Scenarios
Reference Architecture
Step 8
Derived Products
Step 5
Assessment of Architecture Functions
Agency Individual
Multilateral/ Common

# ISECG Mission Scenario



# GER – Preparation for Boots on Mars

- The Global Exploration Roadmap outlines the following Human Exploration Preparatory Activities to extend our presence into the solar system:
  - Use of the ISS for Exploration
  - Robotic (precursor) Missions
  - Advanced Technology Development
  - Development of New Space Systems and Infrastructure
  - Analogue Activities
  - Managing Health and Human Performance Risks

# Capabilities and Enablers

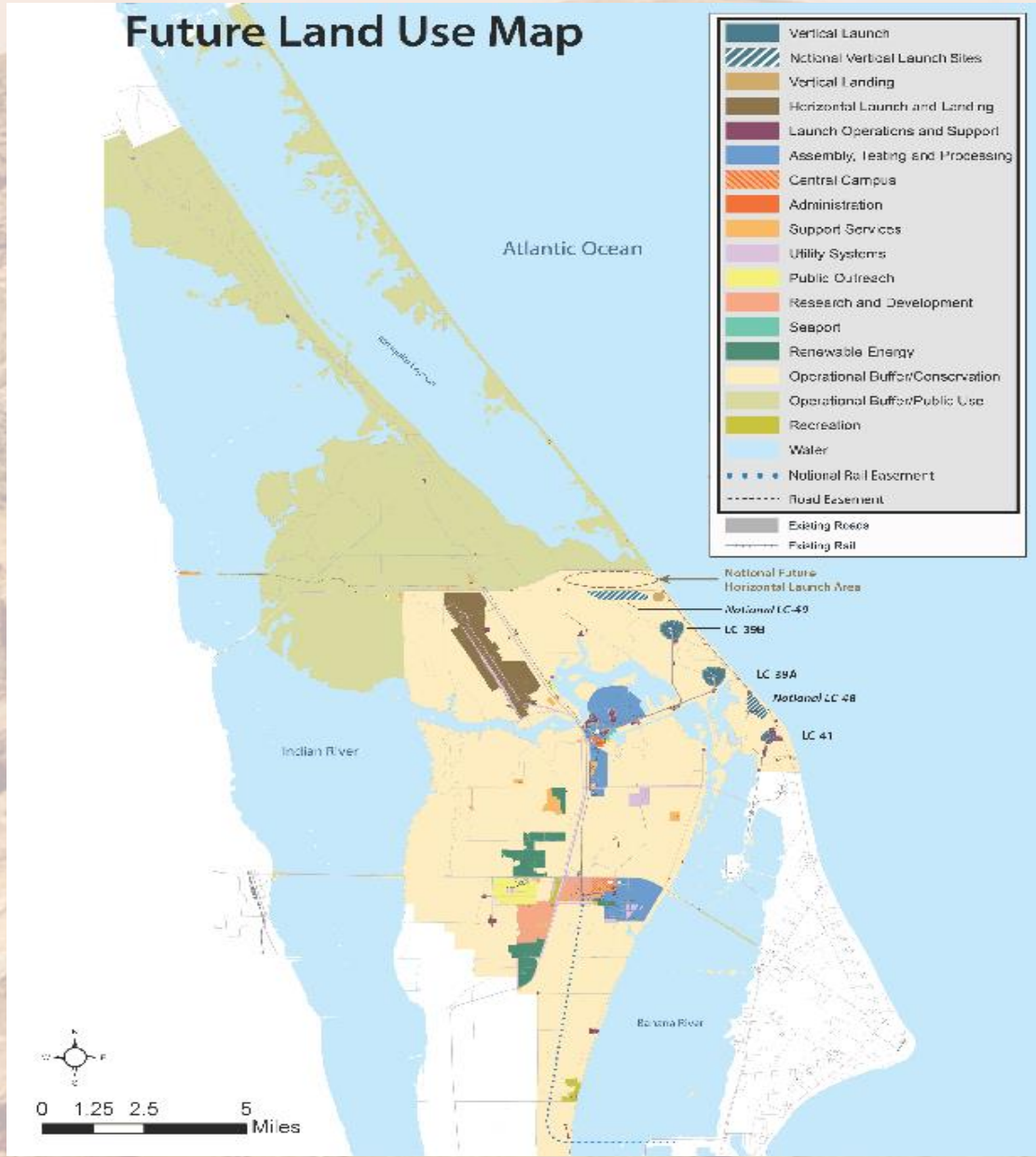
# Spaceport Evolution at KSC

| Timeframe | Theme |
|---|---|
| Pre-2012 | Focused Support for NASA Programs |
| Near Term | Focused Support for Continuing NASA Programs with Emerging Commercial Integration; Economic Sustainability |
| Long Term | Continuing Support for NASA Programs with Balanced Commercial Integration |
| Future: Beyond 2032 | Continued Support for NASA Programs; Fully Leverage All Assets and Land Area Resources; Optimized Diversified Commercial Integration |

Spaceport models like Kennedy Space Center are changing toward airport-like operations that include government and commercial interests

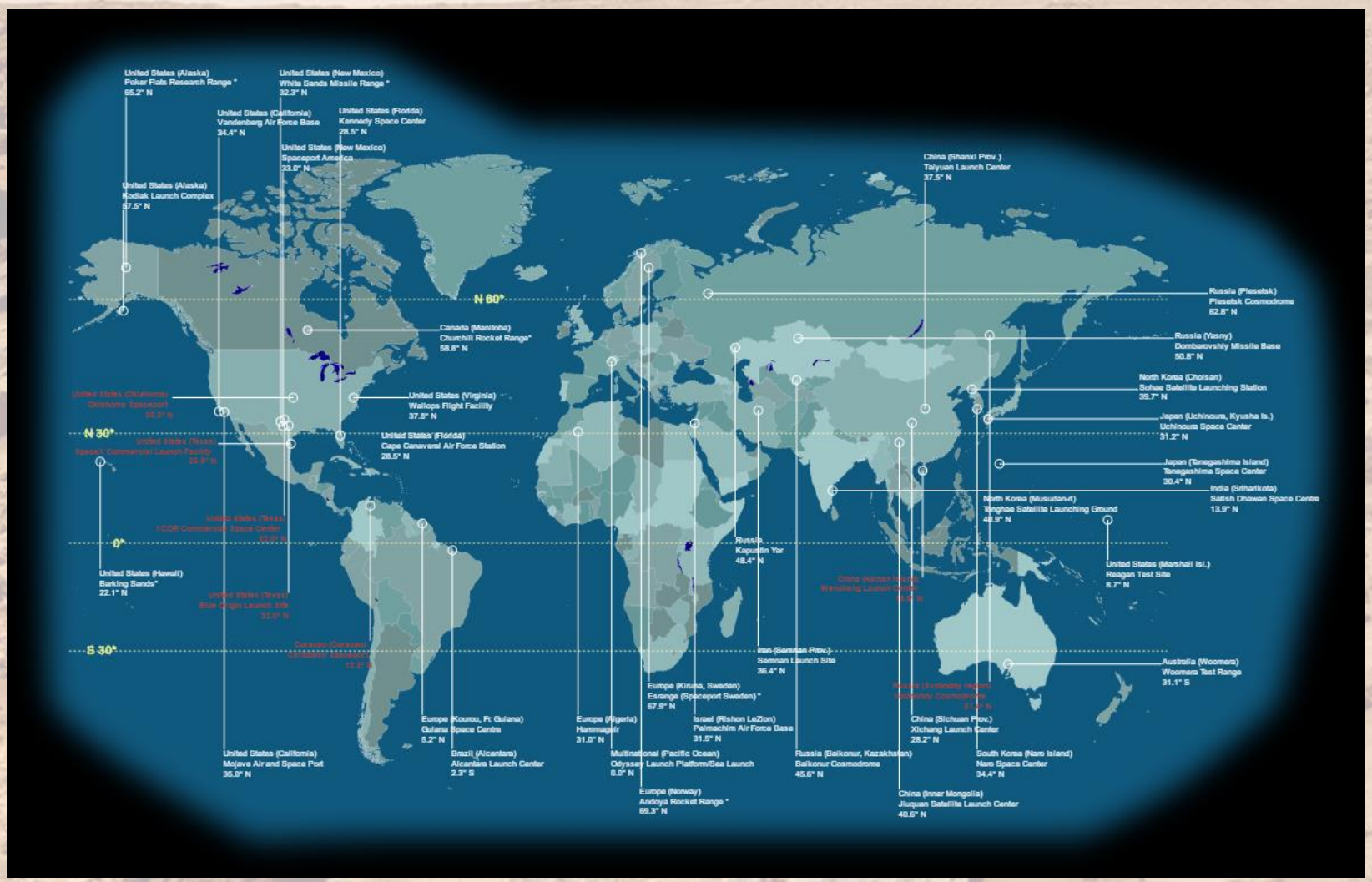
Spaceports are getting planned by architects and city planners for these multiple interests
Includes:

- Administrative Areas
- Transportation
- Recreation
- Utilities
- Public Outreach
- Central Campus
- Horizontal and Vertical Launch and Landing Facilities
- Operational Buffers
- Notional Growth Areas Identified




Adobe Acrobat Document

# Launch Sites around the World




**These planning lessons apply not only at KSC but at spaceports all over the world. And they will apply to destination spaceports as well**

Notional image of spaceports around the world from https://integratedspaceanalytics.com/cms/portal/spaceports

# Legal Framework

- Fundamental principles – Concept of space as the province of all humankind, the freedom of exploration and use of outer space by all states without discrimination, and the principle of non-appropriation of outer space.
- The primary goals of space law are to ensure a rational, responsible approach to the exploration and use of outer space for the benefit and in the interests of all humankind.
- United Nations Office for Outer Space Affairs (NOOSA) Space Law
  http://www.unoosa.org/oosa/en/ourwork/spacelaw/index.html
- Space Treaties & Principles
  http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html

# Legal Framework
# Utilization of Space Resources

- Recovery and Utilization of Space Resources – Scientific vs Commercial (Profit)
- 1967 OST (widely ratified) & 1979 Moon Agreement (poorly ratified)
- Differing views in OST Interpretation – Article 1 right to utilize resources for private commercial use consistent/not consistent for celestial bodies
- Further detailed information from UNOOSA, Legal Subcommittee 56th Session April 2017, Legal Models Utilization of Space resources http://www.unoosa.org/oosa/en/ourwork/copuos/lsc/2017/symposium.html

# Space Resource Regulation

TITLE IV--SPACE RESOURCE EXPLORATION AND UTILIZATION

*Space Resource Exploration and Utilization Act of 2015*

(Sec. 402) The bill directs the President, acting through appropriate federal agencies, to:

- facilitate the commercial exploration for and commercial recovery of space resources by U.S. citizens;
- discourage government barriers to the development of economically viable, safe, and stable industries for the commercial exploration for and commercial recovery of space resources in manners consistent with U.S. international obligations; and
- promote the right of U.S. citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference, in accordance with such obligations and subject to authorization and continuing supervision by the federal government.

A U.S. citizen engaged in commercial recovery of an asteroid resource or a space resource shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell it according to applicable law, including U.S. international obligations.

(Sec. 403) It is the sense of Congress that the United States does not, by enactment of this Act, assert sovereignty or sovereign or exclusive rights or jurisdiction over, or ownership of, any celestial body.

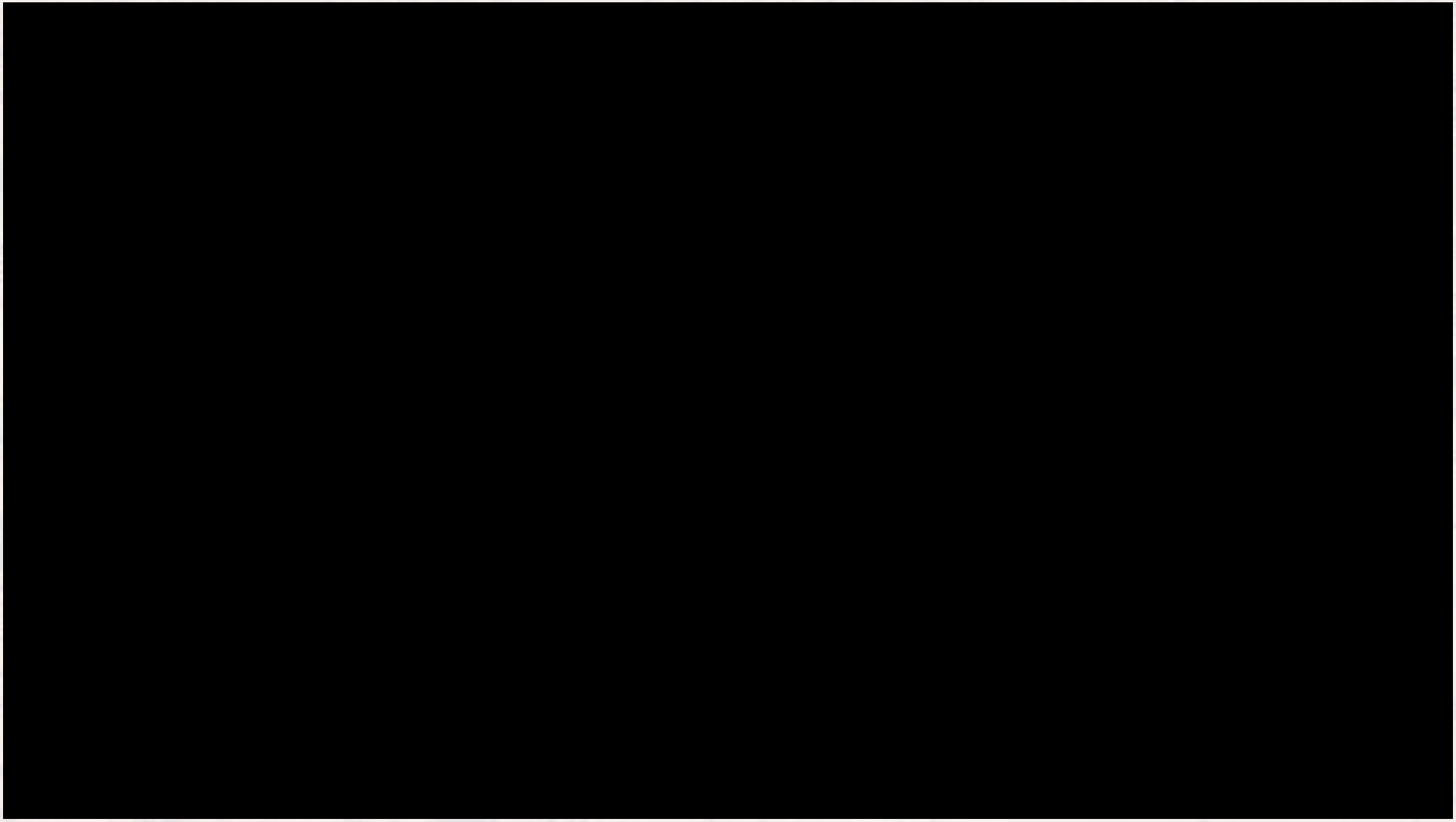
# Commercial Engagement

- NASA Next Space Technologies for Exploration Partnerships (STEP) Habitat Systems – Phase 2
  - 6 commercial companies defining architectures for the Deep Space Gateway
  - Phase 3 Solicitation ~2019 for flight systems
- Commercial Partnerships facilitated through Space Act Agreements https://www.nasa.gov/open/space-act.html
- Regulatory Barriers to commercial investment/participation

# Biggest challenge to getting to the Vision?

- In-situ Resource Utilization (ISRU) – living off the land using available resources for fuel, life support, etc.
- Food Production - growing plants, fish, etc. and sustaining life using what you bring from Earth
- Human health – radiation damage during transit and at Mars and reduced gravity adaptation
- Cargo upmass and transportation to Mars – cost and availability for supplies from Earth
- Policy – legal and commercial barriers
- Many, many more…

# Inspiration: Video – Mars Exploration Zones

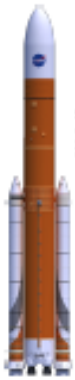
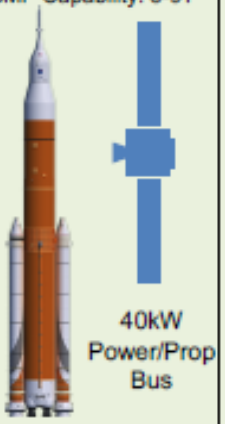
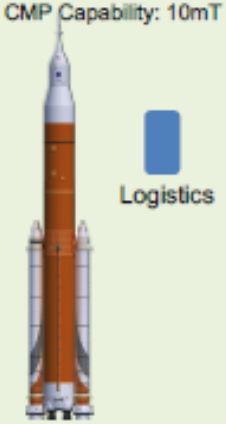
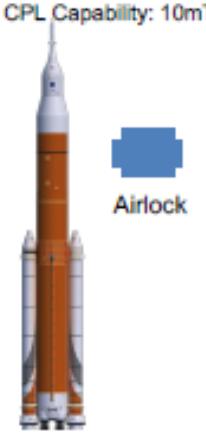
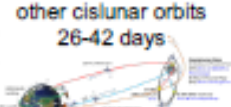
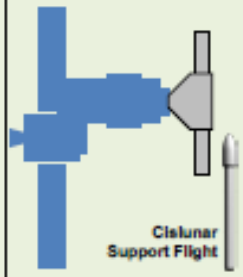
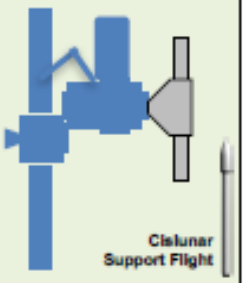
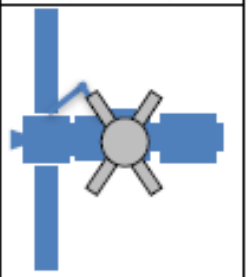


# Any Questions?

# Notional SLS manifest for Deep Space Gateway and Deep Space Transport

# Phase 1 Plan

**Establishing deep-space leadership and preparing for Deep Space Transport development**

| | | Deep Space Gateway Buildup | | | |
|---|---|---|---|---|---|
| EM-1 | Europa Clipper | EM-2 | EM-3 | EM-4 | EM-5 |
| | | **2018 - 2025** | | | **2026** |
| SLS Block 1<br>Crew: 0 | SLS Block 1B Cargo | SLS Block 1B<br>Crew: 4<br>CMP Capability: 8-9T | SLS Block 1B<br>Crew: 4<br>CMP Capability: 10mT | SLS Block 1B<br>Crew: 4<br>CMP Capability: 10mT | SLS Block 1B<br>Crew: 4<br>CPL Capability: 10mT |
|  |  Europa Clipper (subject to approval) |  40kW Power/Prop Bus |  Habitation |  Logistics |  Airlock |
| Distant Retrograde Orbit (DRO)<br>26-40 days | Jupiter Direct | Multi-TLI Lunar Free Return<br>8-21 days | Near Rectilinear Halo Orbit (NRHO)<br>16-26 days | NRHO, w/ ability to translate to/from other cislunar orbits<br>26-42 days | NRHO, w/ ability to translate to/from other cislunar orbits<br>26-42 days |
|  |  |  |  |  |  |
| **Gateway (blue) Configuration (Orion in grey)** | |  |  Cislunar Support Flight |  Cislunar Support Flight |  |

These essential Gateway elements can support multiple U.S. and international partner objectives in Phase 1 and beyond

**Known Parameters:**

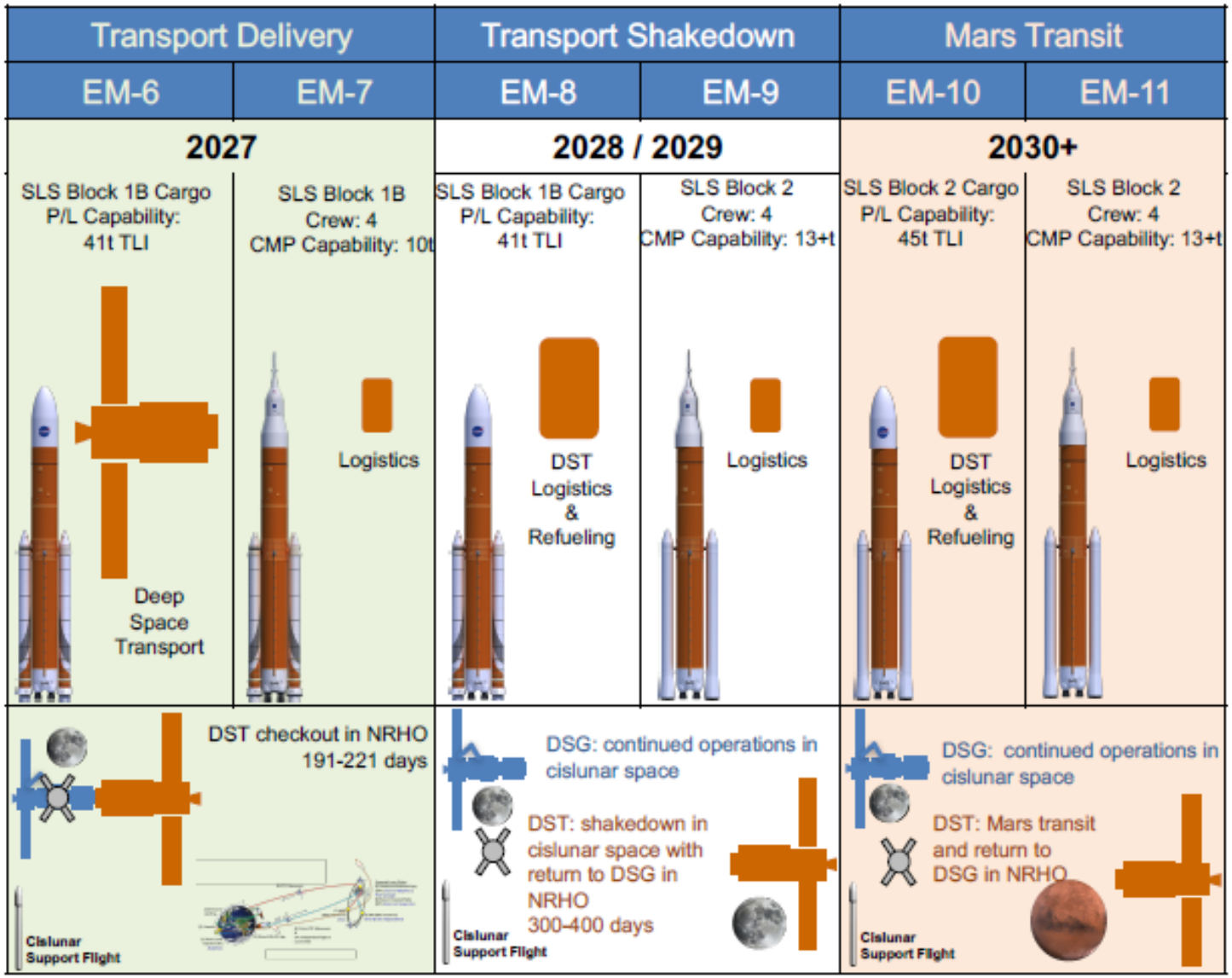
- Gateway to architecture supports Phase 2 and beyond activities
- International and U.S. commercial development of elements and systems
- Gateway will translate uncrewed between cislunar orbits
- Ability to support science objectives in cislunar space

**Open Opportunities:**

- Order of logistics flights and logistics providers
- Use of logistics modules for available volume
- Ability to support lunar surface missions

# (PLANNING REFERENCE) Phase 2 and Phase 3

## Looking ahead to the shakedown cruise and the first crewed missions to Mars




Reusable Deep Space Transport supports repeated crewed missions to the Mars vicinity

**Known Parameters:**

- DST launch on one SLS cargo flight
- DST shakedown cruise by 2029
- DST supported by a mix of logistics flights for both shakedown and transit
- Ability to support science objectives in cislunar space

**Open Opportunities:**

- Order of logistics flights and logistics providers
- Shakedown cruise vehicle configuration and destination/s
- Ability to support lunar surface missions